Hydrogeomorphological approaches to understanding flood hazards and flood-risks management in NW Rwanda

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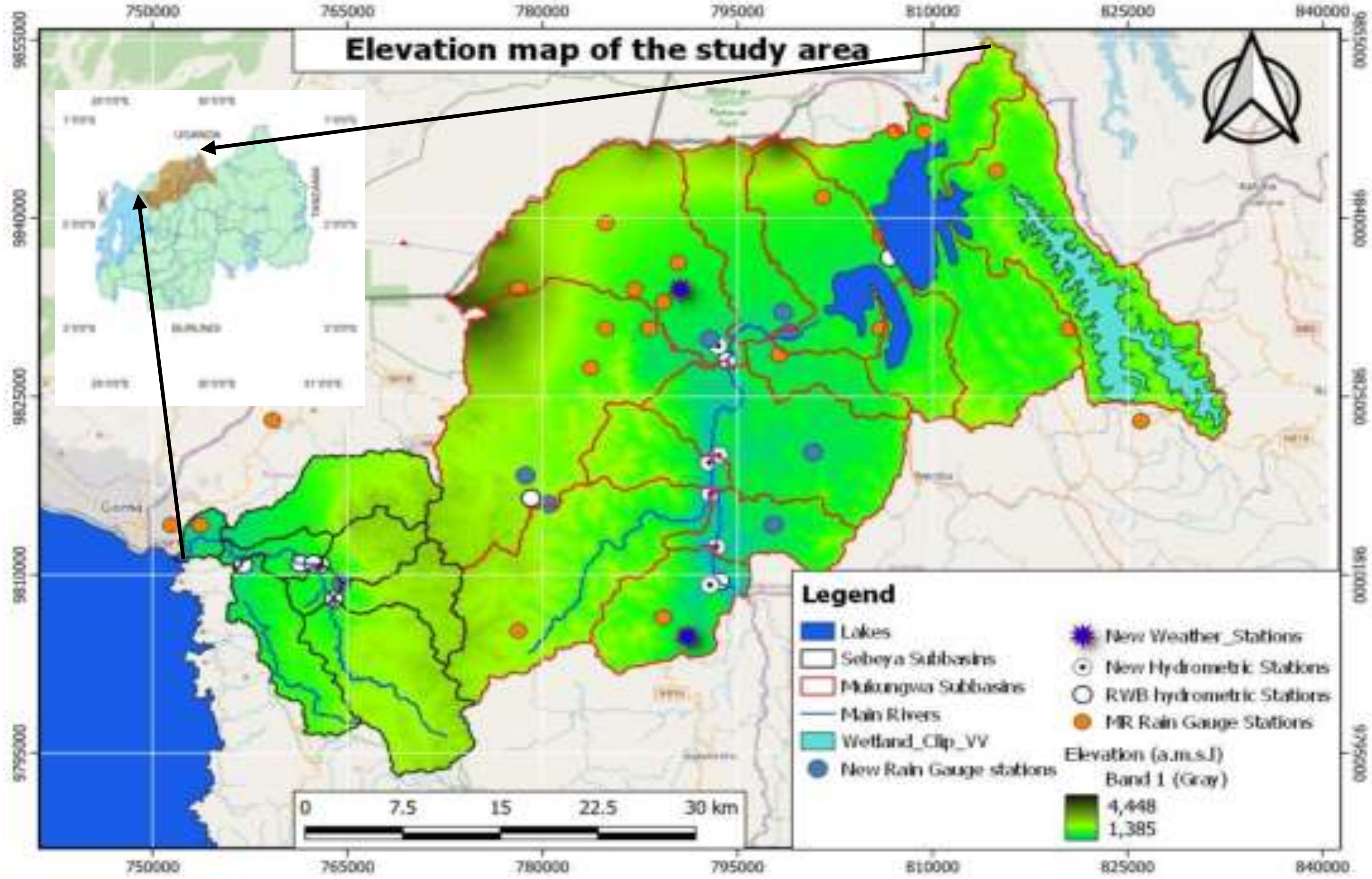
Outlines

- Research context
- Objectives
- Methodology
- Preliminary Results and Discussion
- Conclusion and Next Steps



Research context and objective,

- ❖ Recorded hydrologic data in many areas of the World show a wide range of variability and change.
- ❖ The hydrologic extreme events, such as floods and droughts "appear" to occur more frequently than before.
- ❖ Population pressure and LULC change/variabilities might be among the effects of the temporal and spatial variations of water resources

- **Objective: "Demonstrate that it is possible to find, with good accuracy, the main factors influencing Rainfall-Runoff (RR) response by the extent of occurrence of flood events in relation to topography, soil characteristics, and LULC, based on representative sub-catchments taken as sites of monitoring, in Mukungwa and Sebeya watersheds".**

Specific objectives

1) To analyze the main factors influencing rainfall-runoff response regarding flood events;

2) To provide detailed and reliable short-term RR observations by a set of eight representative sub-catchments with contrasting soil types, topographies, and LULC conditions;

3) To develop tools that can help in better understanding flood hazards and flood risks, and better design flood management projects, based on RR relation, LULC, soil types, and other potentially relevant factors;

4) [To estimate the probable maximum floods that can cause serious threats to lives, properties, and hydraulic infrastructure].

Methodology

- Eight sub-catchments have been chosen as the monitoring sites

- Six hydrometric stations equipped with one TD-diver and one staff gauge for each have been set up in the Mukungwa catchment to complete five and one operating water head sensors in Sebeya and Mukungwa respectively

- Eight automatic rain gauges and two complete weather stations were installed in the study area to check the accuracy and complement the existing network stations of the Meteo Rwanda).

- Current meter/flow probe and float methods used to measure the flow velocity of the monitored rivers

Methodology cont'd

- Twelve existing rain gauges have been chosen for determining the incremental rainfalls
- DEM and LULC maps for determining and processing inputs for models
- Stochastic methods (Gumbel (EV1), and Log Pearson Type 3(LP3) Distributions); hydrological (HEC-HMS) and hydraulic (HEC-RAS) models used to evaluate factors influencing the rainfall-runoff response to flood hazards and flood risks events
- Multicriteria analysis used for flood susceptibility mapping [(topography (10%) slope (15%), LULC(10%), precipitation(35%), proximity to rivers (30%)], comparison with the HEC-RAS outputs (inundation maps for different return periods)
- Multi-stage IDF development to evaluate rainfall-runoff evolution
- Observation data used for model calibration and validation

Exploratory field survey, construction and installation of hydrology equipment, and data collection

(a)Identification of the monitoring site near the outlet of the Gaseke river

(b)Identification of the monitoring site near the outlet of the Nyamutera river

©Bihongora site has been rejected

(d)Constructed hydrometric stations: Gaseke and Giciye

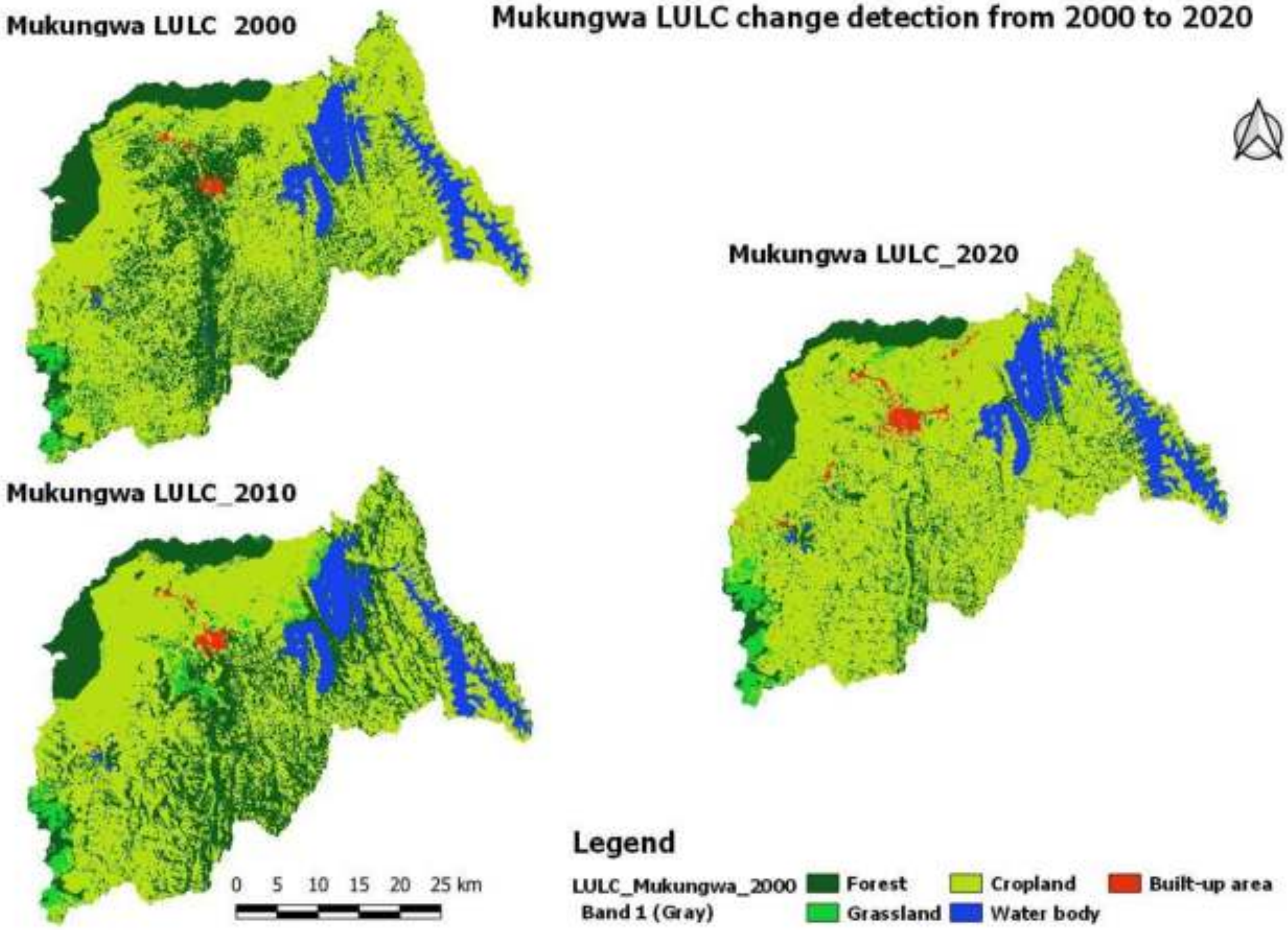
(e, f, and g): Weather station: Muramba, (h) Installation of TD-Diver: Nyamutera, (i) Rain gauge: Rusongati

(j)Flow measurement using float (top width, length, time, depths of each interval)

(k)Flow measurement using flow probe

(l)Downloading TD and baro diver data

Preliminary Results and Discussion

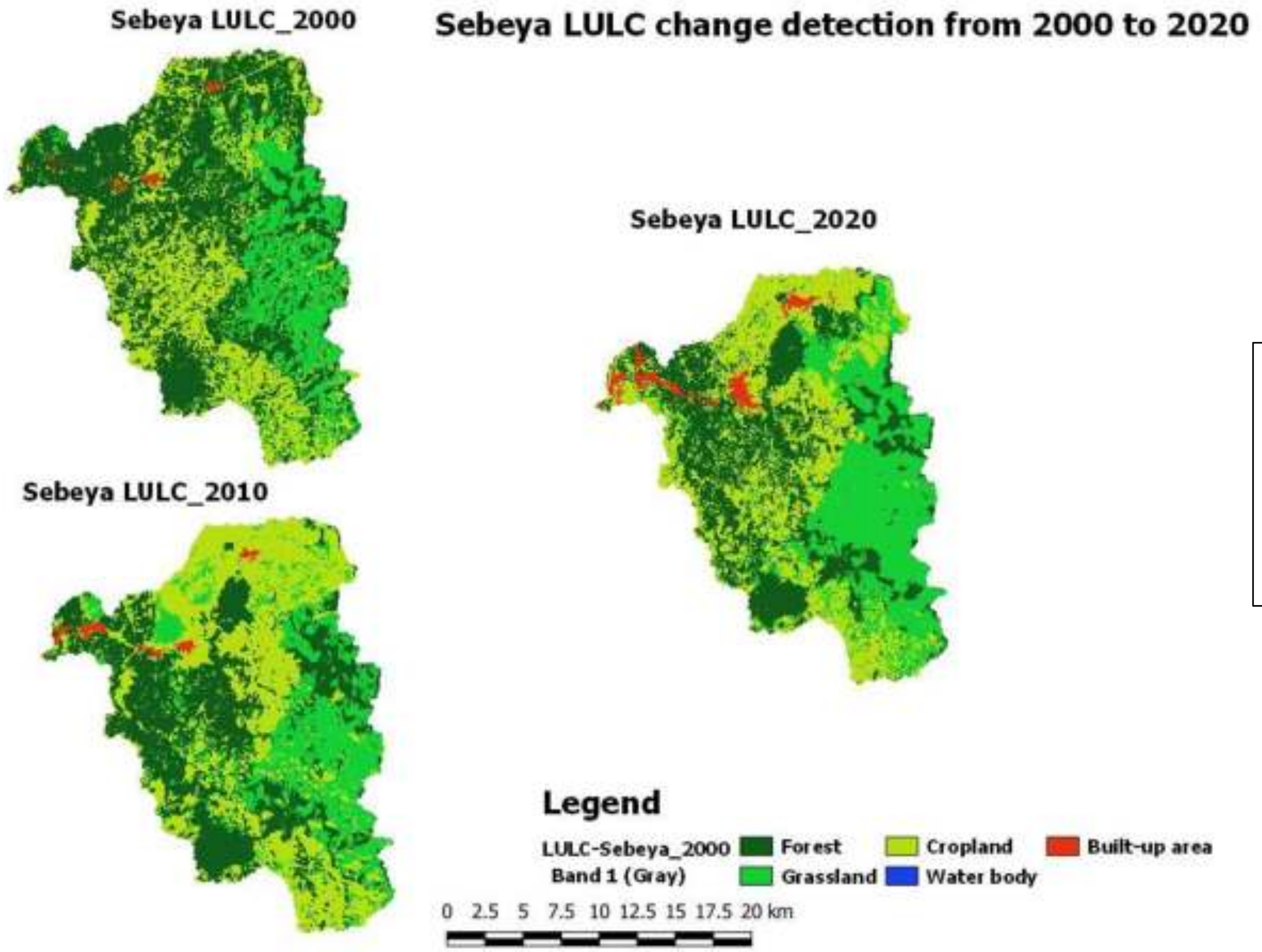


In 20 years, forested areas, grassland, cropland, water body, and built-up areas have been changed in the Mukungwa watershed

Land cover change matrix of Mukungwa (2000-2020)

LULC in 2000	**LULC in 2020**							
	Forest (m^2)	Grassland(m^2)	Cropland (m^2)	Water body (m^2)	Built-up area (m^2)	Total (m^2)	Total (km^2)	Percentage (%)
Forest (m^2)	203,798,435	16,514,646	296,819,856	4,649,263	6,840,129	528,622,331	528.6	**29.7**
Grassland (m^2)	2,296,613	19,032,696	6,103,513	2,711	22,595	27,458,130	27.5	**1.5**
Cropland (m^2)	111,171,081	26,051,782	920,248,658	12,746,609	8,356,743	1,078,574,876	1,078.6	**60.5**
Water body (m^2)	2,518,953	2,049,869	6,651,230	128,819,121	0	140,039,175	140.0	**7.9**
Built-up area (m^2)	48,806	2,711	339,837	6,326	7,688,818	8,086,500	8.1	**0.5**
Total (m^2)	319,833,891	63,651,705	1,230,163,096	146,224,033	22,908,287	1,782,781,014	1,782.8	**100.0**
Total (km^2)	319.8	63.7	1,230.2	146.2	22.9	1,782.8		
Percentage (%)	**17.9**	**3.6**	**69.0**	**8.2**	**1.3**	**100.0**		

RESULTS AND DISCUSSION

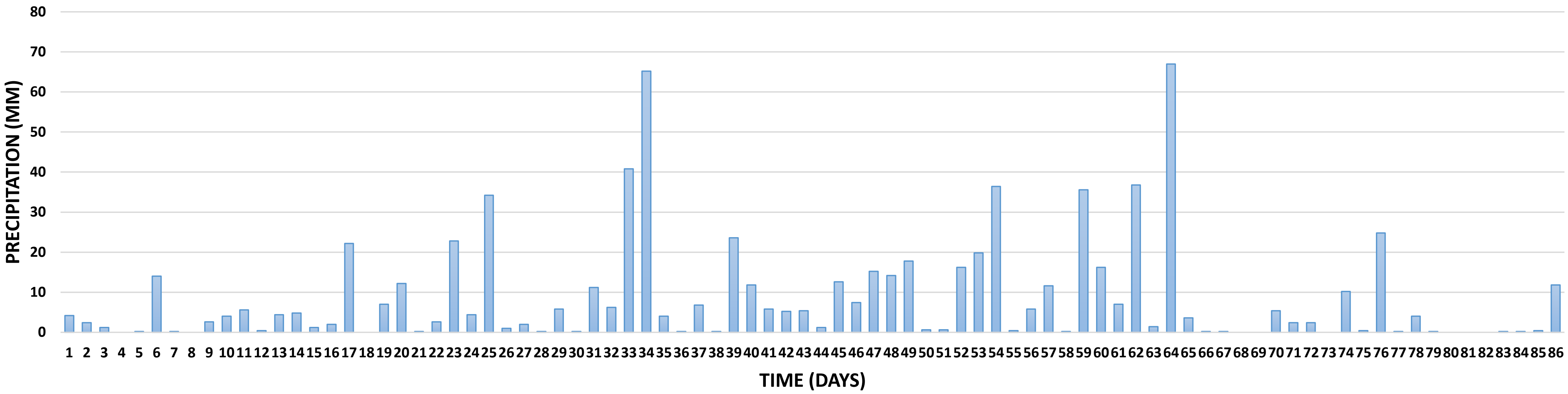


In 20 years, forested areas, grassland, cropland, water body, and built-up areas have been changed in the Sebeya watershed

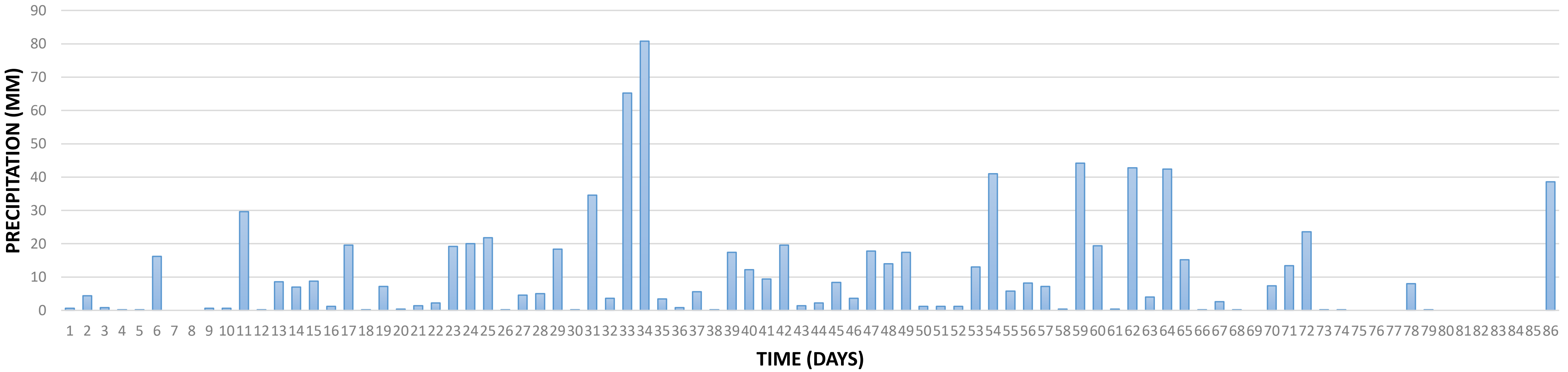
Land cover change matrix of Sebeya (2000-2020)

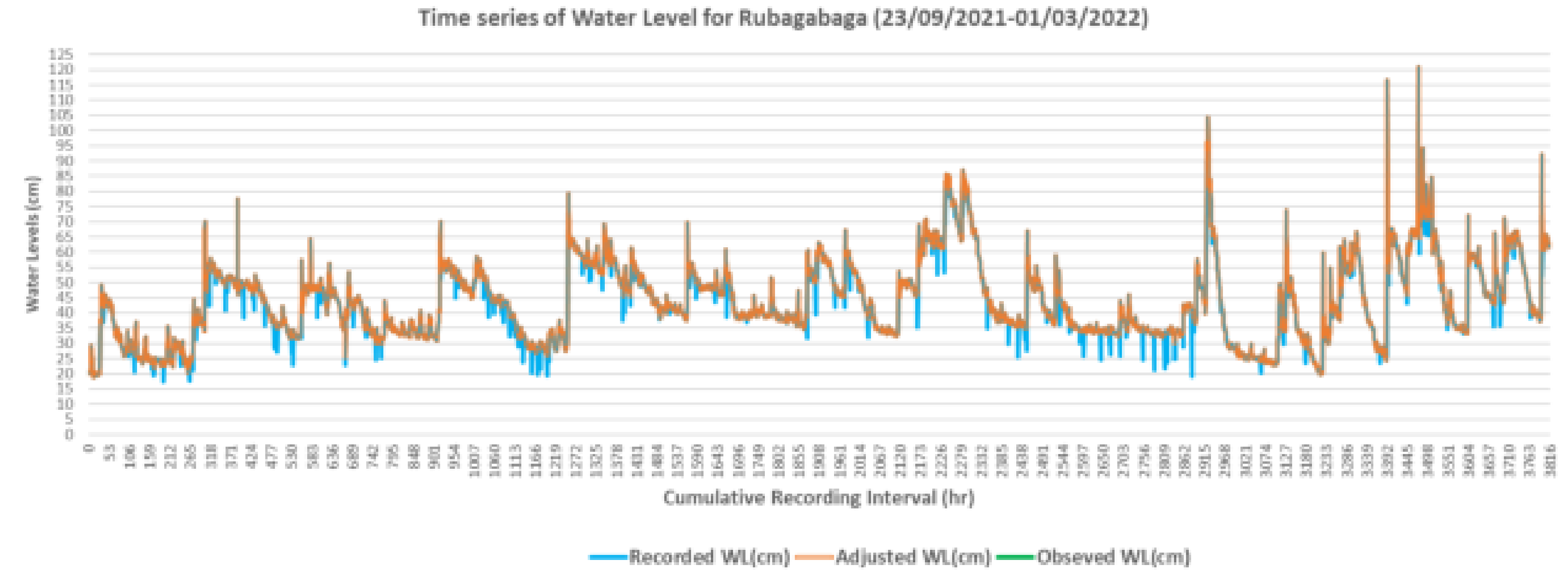
LULC in 2000	LULC in 2020						
	Forest (m^2)	Grassland(m^2)	Cropland(m^2)	Water body (m^2)	Built-up area (m^2)	Total [Km^2]	Percentage [%]
Forest (m^2)	87,024,557	31,602,156	63,574,880	4,519	4,782,125	187.0	**50.9**
Grassland (m^2)	5,646,179	56,658,830	6,962,145	3,615	75,921	69.3	**18.9**
Cropland (m^2)	28,495,718	21,737,837	56,415,702	0	1,766,069	108.4	**29.5**
Water body (m^2)	50,614	28,018	120,208	0	9,038	0.2	**0.1**
Built-up area (m^2)	209,686	1,807	122,919	0	1,794,087	2.1	**0.6**
Total [Km^2]	121.4	110.0	127.2	0.0	8.4		
Percentage [%]	**33.1**	**30.0**	**34.7**	**0.0**	**2.3**		

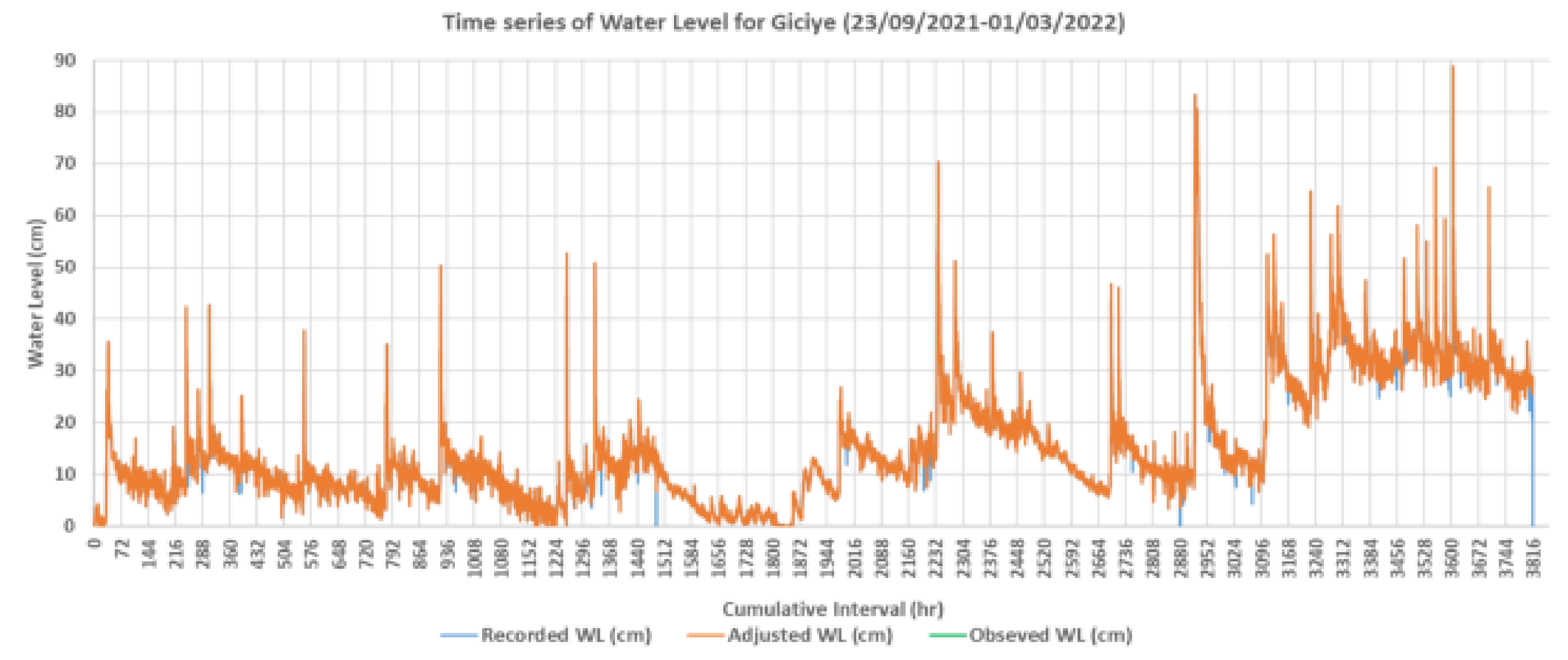
DAILY RAINFALL RECORDS FROM 01/03/20203 TO 24/05/2023 AT MUKO STATION



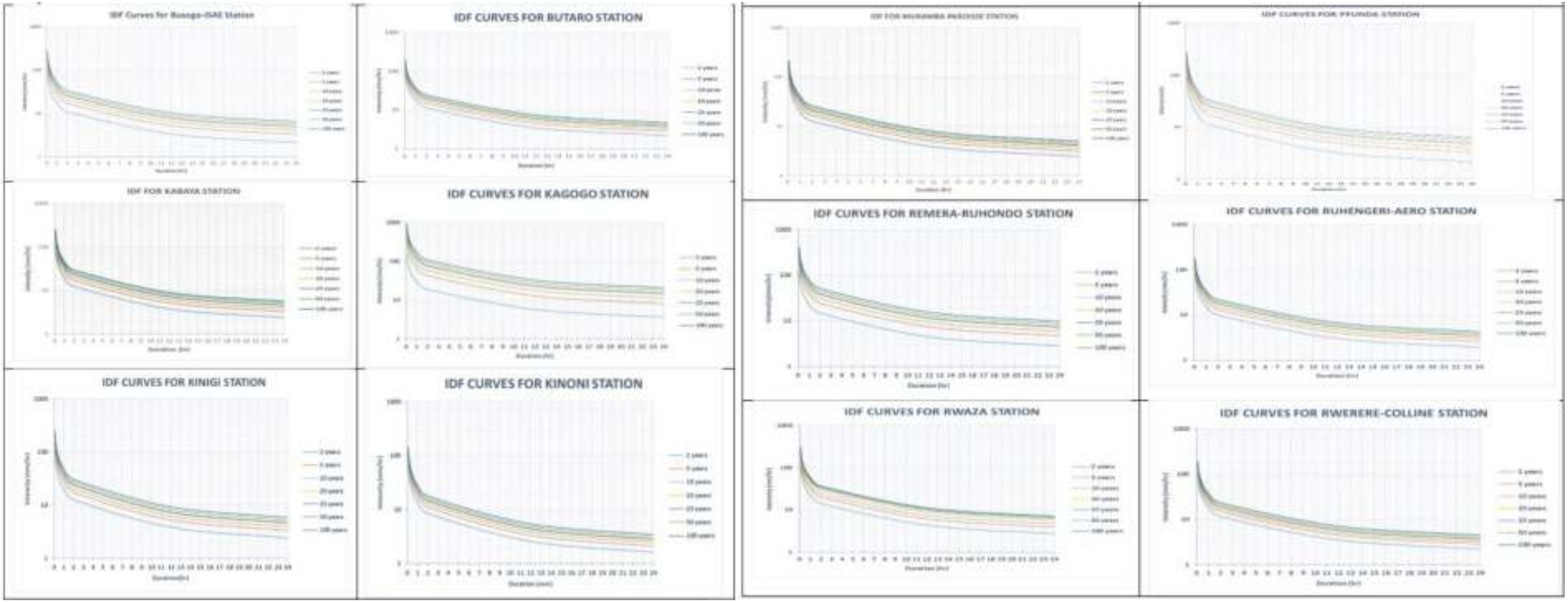
DAILY RAINFALL RECORDS FROM 01/03/20203 TO 24/05/2023 AT BUSENGO RAIN GAUGE

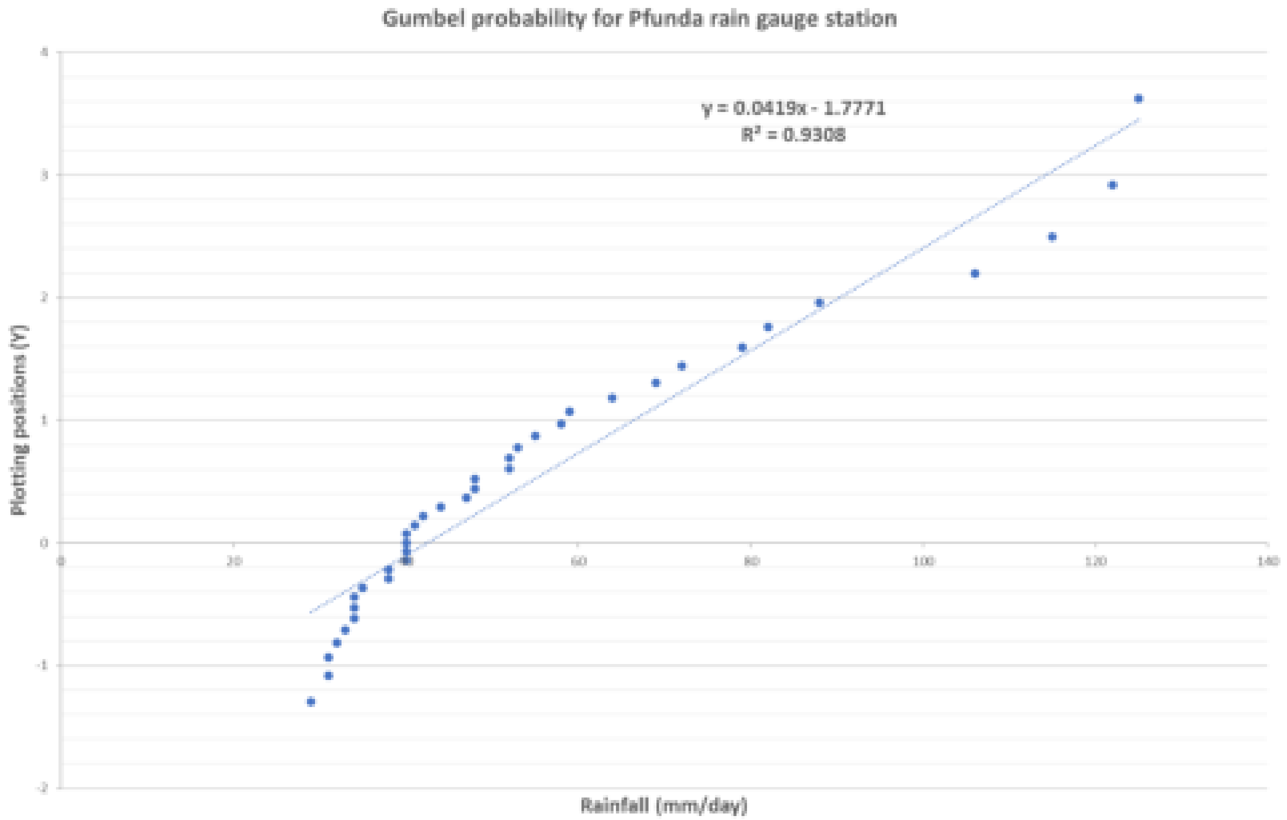



Time series of Water Level for Rubagabaga (23/09/2021-01/03/2022)
Water Levels (cm)
Cumulative Recording Interval (hr)
Recorded WL(cm)
Adjusted WL(cm)
Obseved WL(cm)


Time series of Water Level for Giciye (23/09/2021-01/03/2022)
Water Level (cm)
Cumulative Interval (hr)
Recorded WL (cm)
Adjusted WL (cm)
Obseved WL (cm)

DEVELOPPED IDF CURVES FOR 12 RAINGAUGE STATIONS OF THE STUDY AREA

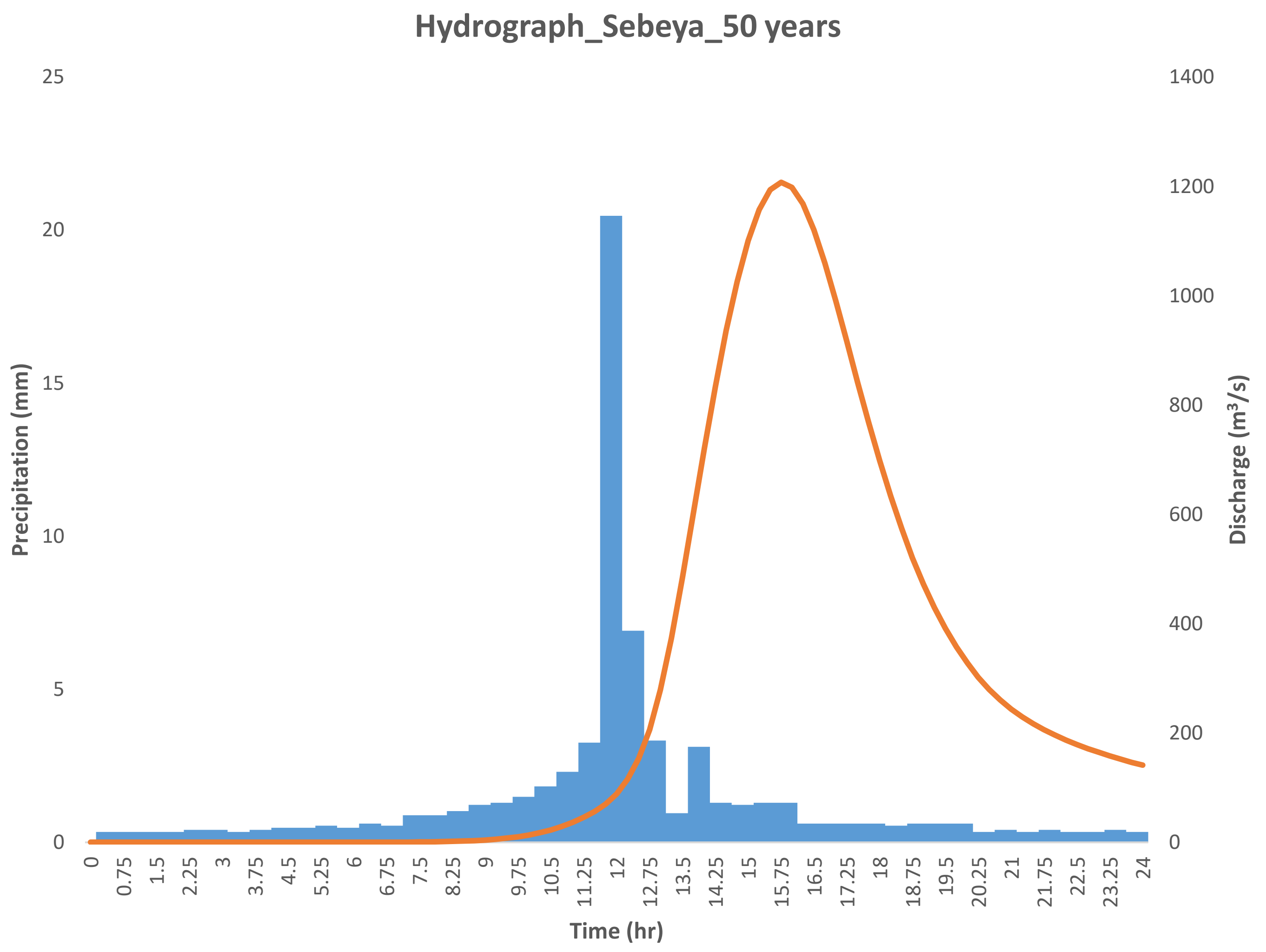




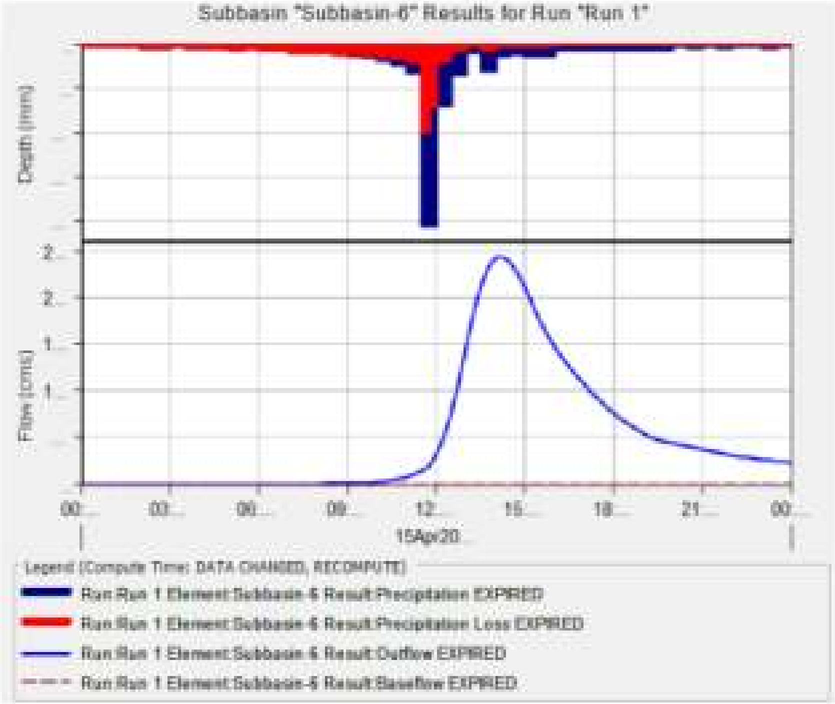
Return Periods T=1/(1-PL)	PL	Y	Rainfall events (mm/day)	Intensities (mm/h)
2	0.5	0.367	50.67	**30.605**
5	0.8	1.500	79.81	**48.204**
10	0.9	2.250	99.10	**59.856**
20	0.95	2.970	117.60	**71.033**
25	0.96	3.199	123.47	**74.578**
50	0.98	3.902	141.56	**85.5**
100	0.99	4.600	159.51	**96.341**

From the Gumbel probability, we have computed the independent variable x which is the rainfall. This is used to determine the incremental rainfalls for different return periods that are used in the HEC-HMS model in time-series data

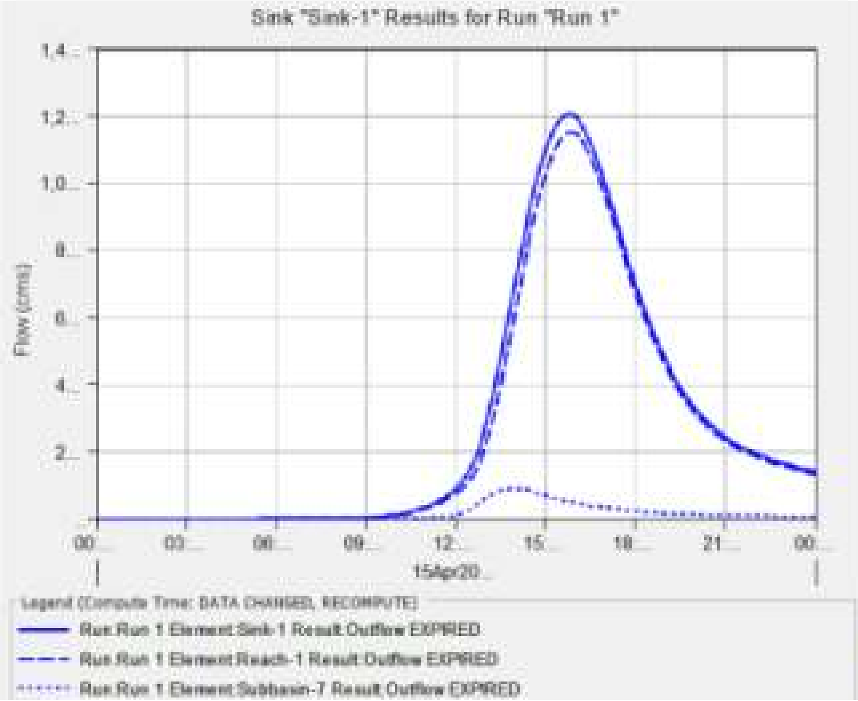
The figure above shows an example of the Gumbel probability for Pfunda rain gauge station. It is used to determine the peak rainfalls of different return periods (2, 5, 10, 20, 25, 50, and 100 years). In this research, we have established twelve Gumbel probabilities used to determine the incremental rainfalls that have been used as rainfall time series for each rain gauge station. These are among the inputs of HEC-HMS model used to establish RR relationships.



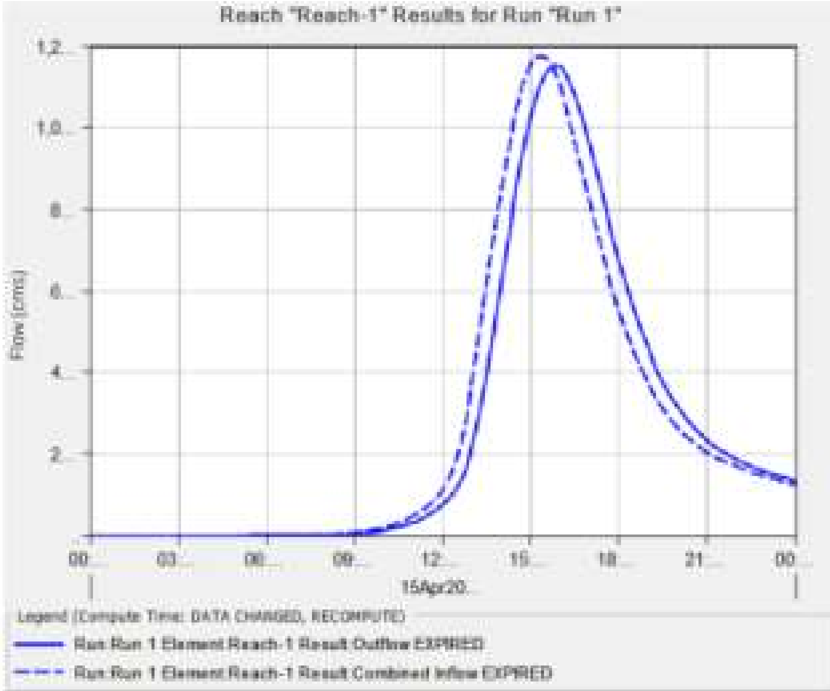
The figure above is the 50 years-hydrograph for Pfunda river by using Log Pearson distribution (LP3). It represents the RR relationship as a function of time. The bar chart is the hyetograph (P=f(t)) and the continuous graph in red color is the corresponding hydrograph (Q=f(t)). The time interval between the peak rainfall and the peak runoff is the lag time that is one of the inputs of the HEC-HMS model. The hydrograph is used in hydraulic structure design such as dams, spillways, culverts, etc.



The figure above is the unit hydrograph simulated using HEC-HMS Model for Pfunda. The red bar chart represents the infiltration while the blue bar chart represents the effective rainfall (Pe), and the continuous blue curve represents direct runoff (Qe).



The figure is the combination of hydrographs of the outflow, lower reach, and downstream sub-catchment of Sebeya respectively. It was generated by the simulation using HEC-HMS model for a 50 years return period rainfall event.



The figure above represents flow routing at the sink of Sebeya (the way of estimating downstream hydrograph from upstream hydrograph). It was generated by the HEC-HMS model and is useful during the analysis of the attenuation of flood events due to the presence of retention structures.

Conclusion and next steps

- In the last 20 years, forested areas, grassland, cropland, water body, and built-up areas were changed
- These have affected the rainfall-runoff response at the sub-catchments and the whole catchments levels in terms of increases in runoff volumes
- The decrease in forest and increase in grassland/cropland covers have affected the increase in runoff volume
- Increase in sedimentation loads from both landslides and soil erosion, and poor drainage systems are among the main sources of flood hazards
- We are still analyzing other influential factors that cause flood hazard events,
- We are still collecting and analyzing data that will help in model calibration and validation, but
- Land cover restoration, especially afforestation, construction and maintenance of retentions, and improved drainage system can contribute to the reduction of the increase in runoff volumes as well as in flood management in the study area

Thanks for your Kind attention